Energy Projection Analysis of Solar Energy for Water Pump System Using Gridline Power with Focus on Control System

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ABSTRACT

Experiment is undertaken to determine the possibilities of creating a solar powered pump system to reduce the power wastage in an Evacuated Tube Solar Collector water circulation system at Pekan campus (3˚ 30’ N, 103˚ 25’ E) Faculty of Mechanical Engineering, University Malaysia Pahang. The experiment kicks off by creating a test rig to hold the solar panel in place and creating a cut-in cut-out (CiCo) system to help reduce the pump energy consumption. CiCo system is developed to cut-in and cut-out the pump based on the temperature difference between the Evacuator outlet and the storage tank. Malaysia lies in the equatorial zone with an average daily solar insolation of more than 900 W/m^2 and can reach a maximum of 1200 W/m^2 for most of the year. Due to different weather pattern which will block and reduce the solar isolation, CiCo system can help reduce the power consumption of the pump when the temperature has reach the threshold set in the codding set in PIC18F4550 detected by two thermostat LM35DZ. G.T. Power RC Wattmeter is connected to a solar panel to determine the total energy output of the panel. A multifunctional mini ammeter is connected to the pump to measure the energy consumption of the pump with or without connecting the CiCo system. Based on the experiment the maximum panel required to create a solar powered pump system without using the CiCo system is 18 panels. However when connected to CiCo system the number of panel required is decreased to five panels. This show the minimum required panel if UMP decided to create a solar powered pump system in the campus.

ABSTRAK

Eksperimen ini dijalankan untuk menentukan kemungkinan mewujudkan sistem pam tenaga solar untuk mengurangkan pembaziran tenaga dalam sistem peredaran air ETSC di kampus Pekan (3˚ 30' N, 103˚ 25' E) Fakulti Kejuruteraan Mekanikal, Universiti Malaysia Pahang. Eksperimen ini bermula dengan mewujudkan satu pelantar ujian untuk panel solar dan mewujudkan sistem buka dan tutup pam (CiCo) untuk membantu mengurangkan penggunaan tenaga pam. Sistem CiCo direka untuk buka dan tutup pam berdasarkan perbezaan suhu di dalam ETSC dan juga tangki simpanan. Malaysia terletak di zon khatulistiwa dengan purata kuasa solar harian lebih daripada 900W/m^2 dan boleh mencapai 1200 W/m^2 bagi keseluruhan tahun. Disebabkan corak cuaca yang berbeza yang akan menghalang dan mengurangkan kuasa solar, sistem CiCo ini boleh membantu mengurangkan penggunaan tenaga pam apabila suhu telah mencapai had yang ditetapkan dalam PIC18F4550 yang dikesan oleh dua buah termostat LM35DZ. G.T. RC alat pengukur watt disambungkan kepada panel solar untuk menentukan jumlah tenaga panel. Sebuah ammeter pelbagai fungsi disambungkan kepada pam untuk mengukur penggunaan tenaga pam tanpa menyambung sistem CiCo dan menyambung system CiCo. Berdasarkan eksperimen panel maksimum yang diperlukan untuk mewujudkan satu sistem pam solar tanpa menggunakan sistem CiCo ialah 18 panel. Walau bagaimanapun apabila disambung kepada sistem CiCo bilangan panel yang diperlukan dikurangkan kepada lima panel sahaja. Ini menunjuk had minimum yang diperlukan jikalau pihak UMP hendak mewujudkan system pam kuasa solar.

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η	Efficiency of the system
GT	Global solar radiation, W/m^2
n	Leap year/ Non leap year + Day
β	Angle made by the plane surface with the horizontal
I_{sc}	Solar constant
δ	Declination angle
ω_{st}	Hour angle
N_{MAX}	Monthly average of maximum possible sunshine hours per day, in hours
H_O	Monthly average of daily extra-terrestrial radiation on a horizontal surface, kJ/m^2.day
H_g	Monthly average of daily global radiation on a horizontal surface, kJ/m^2.day
a, b	Regression coefficients which vary from site to site
H_d	Monthly diffuse radiation, kJ/m^2.day
H_b	Monthly beam radiation, kJ/m^2 .day
β_{opt}	Optimum angle
I_c	Solar radiation at collector, W/m^2
P_m	Power output, W
E	Input light, W/m^2
A_c	Area of solar cell, m^2

LIST OF ABBREVIATIONS

ETSC	Evacuated Tube Solar Collector
ETC	Evacuated Tube Collector
UMP	Universiti Malaysia Pahang
ETC	Evacuated Tube Collector
PV	Photovoltaic
FKM	Fakulti Kejuruteraan Mekanikal
CiCo	Cut-in Cut-out
AC	Alternating Current
DC	Direct Current
adc	Analog
TEMP	Temperature

CHAPTER 1

INTRODUCTION

1.1 BACKGROUND

The sun is the centre of our solar system. Without sun, it is impossible for a human or living creature to live in this world. During recent years the issue about global warming has become a hot topic among mankind. One of the main contributors towards global warming is the burning of fossil fuel to generate power. To help save Mother Earth, many ideas and design have been brought up to utilize the renewable energy around us such as solar panel, wind turbine geothermal power plant, hydro power station etc.

For a country like Malaysia which sits at the equator of the Earth, harnessing the power of the sun is well encouraged in this country. Malaysia practically haves sunlight shining on it every day without the effect of changing seasons and reduction in daylight time. Photovoltaic (PV) panel and Evacuated Tube Solar Collector (ETSC) is just some of the solar panels available in the market. PV panel converts sunlight directly to electric current and ETSC hat up working fluid with solar energy.

The current ESTC that have been installed in University Malaysia Pahang Pekan Campus uses a pump which runs on AC power from the grid line. The Author approach to this design is to create a pump cut-in and cut-out system based on temperature difference at the ETSC outlet and the storage tank to help reduce the pump energy consumption. To further improve the design, the Author would conduct an energy projection analysis to determine the minimum panel required to create a solar powered pump system.

1.2 PROBLEM STATEMENT

Evacuated tube solar collector (ESTC) is used as the primary solar collector in University Malaysia Pahang Pekan Campus. However during hot weather, the systems will experience high stagnant temperature. The present ESTC water pump is supplied by grid line electricity and run continuously without any regards towards the weather condition.

This system posted a few problems toward the faculty. When there is an electricity outage, the pump will lose its power and stop functioning. The evacuated tube solar collector will face the risk of breaking if the stagnant temperature is too high due to pressure build up by the steam in the collector.

The current pump system is also operated by timer system which causes energy wastage. The pump will continue to operate even when the weather is bad due to rain or cloud. A system must be created to detect the changing in temperature at the Evacuator tube solar collector outlet and within the storage tank, to turn on the pump when necessary to ensure there is no energy wastage and to ensure that the evacuated tube collector will be able to perform at its best condition.

To create a much more environmentally friendly system, a decision is made to reduce or remove the reliance on grid line electricity by introducing the solar PV panel as the main source of electricity power. To minimize the cost for panel installation an energy projection analysis is needed to determine the minimum solar panel required to ensure that the pump can operate when needed.

1.3 PROJECT OBJECTIVES

The main objectives of “Energy Projection Analysis of Solar Energy for Water Pump System Using Gridline Power with Focus on Control System” projects are:

i. To develop an energy projection analysis of solar energy for water pump system using gridline power with focus on control system
ii. To design, analysis and fabricate the bracket for solar panel.
iii. To design and fabricate a control system to control the pump cut-in and cut-out based on the temperature differences.
iv. To determine the minimum solar panel required to create a solar powered pump system.

1.4 PROJECT SCOPE

This project is focused to design and build a solar powered pump system that act as a cooling system for the solar collector to ensure it does not overheat.

Therefore, this project will cover the scope as follows.

i. To design and fabricate a temperature control system for the pump.
ii. To calculate the optimum tilt angle for fix panel in Pekan.
iii. Design, analysis and fabricate a test rig to hold the solar panel at fix angle.
iv. To monitor the PV panel output to determine the minimum required panel for the pump system.
v. To monitor the pump energy usage on and off the CiCo system to determine the amount of power saved.
vi. To collect the data from 9.00 a.m. to 6.00 p.m. to gain the required data for analysis.

1.5 GRANTT CHART

Figure 1.1: Grantt Chart for PSM1

PROJECT ACTIVITY	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
Discussion With Supervisor														
Verify The Project Title, Scope And Objective														
Literature Review														
Calculation For Tilt Angle														
Draft Design for Test Rig														
Selecting Suitable Control System														
Market Survey On Component														
Fabrication Of Control Circuit														
Test Run Of Control Circuit														
Report Writing														
Submit Draft and Log Book														
Presentation FYP 1														

Figure 1.2: Grantt chart for PSM2

PROJECT ACTIVITY	W1	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14	W15
Fabricating of Test Rig															
System set-up															
Testing on System and equipment															
Data Collection															
Analysis Data															
Report Writing															
Submit Draft and Log Book															
Presentation FYP 2															

CHAPTER 2

LITERATURE REVIEW

2.1 INTRODUCTION

This literature review explores about the major scopes in this report which are solar energy, evacuated tube solar collector, photovoltaic panel and solar pump system. The literature review provides a background to the study being proposed. The background may consider previous findings, rationale of the relevant study, methodology or research methods, and theoretical background. Most of the literature reviews have been extracted from journals, books and web site. This is important because this helps avoid the same mistakes made by the previous study. Therefore, with these literature reviews, the project can be run smoothly.

2.2 RENEWABLE ENERGY

Renewable energy is the sources of energy which will always be available. Based on the law of thermodynamics energy is considered to be finite. Renewable energy is the form of energy which would one day finish, however due to the abundance of supply there is no foreseeable end in our or our children’s lifetimes. While this energy must be finite, due to entropy and the laws of thermodynamics, the supply is so large that there is no foreseeable end in our or our children's lifetimes. (The Franklin Institute, 2012)

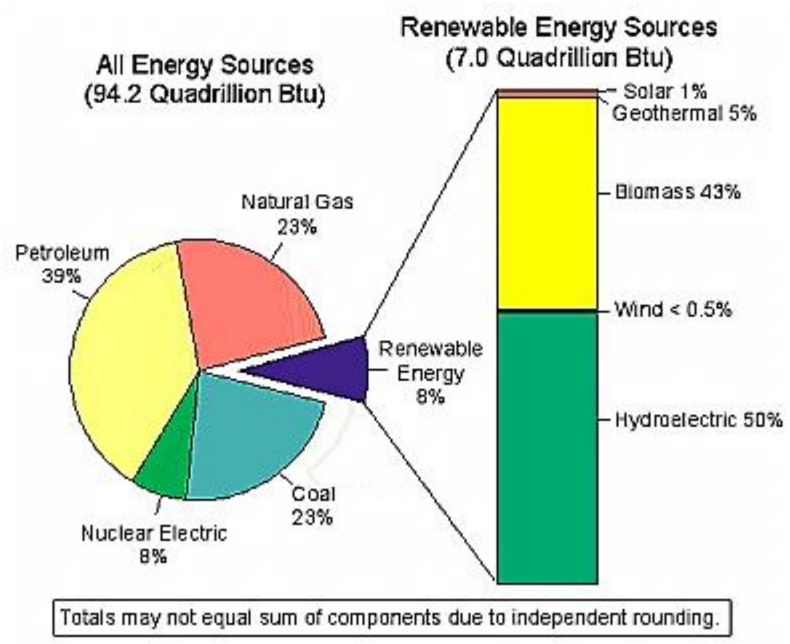

Figure 2.1: World Energy Sources

Source: The Franklin Institute (2012)

Figures 2.1 show the types of energy sources uses through the world and their percentage. Renewable energy only supply around 8 % of the energy source. This is mainly because the high initial cost if compare with the other major energy sources supply such as fossil fuels and uranium. However, as the world run out of our supply of fossil fuels and uranium or the cost of these fuels rises for economic or political reasons, the cost of renewable energy may become much more competitive.

The other important advantage of renewable energy is that it produces much less pollution. Some people believe that if the true costs of pollution, like the medical costs of cancer, were factored into the cost of fossil fuels and uranium, that renewable energy is already cost effective and should be used much more often.

Another requirement to make renewable energy more competitive is more research. The United States government has cut funding for research into solar and other renewable energy. This has left the United States even more likely to be dependent on oil imports far into the future.

2.3 SOLAR ENERGY

The sun is the centre of our solar system. It has been burning and supplying us with solar energy for an average of 4.5 billion years. Astronomers believe the sun has enough fuel supply to burn another 5 billion years. (Elish, 2006).This solar energy is considered one of the best renewable energy because of its sustainability. Lives on earth start from the radiation receive from the sun. This energy is generated when the hydrogen in the sun's core fuse together to become helium. During the process of fusion part of the mass of the hydrogen converted into energy. In a sense, the sun is a huge fusion reactor. (Deutsche Gesellschaft Fur Sonnenenergie , 2012).

The distance between the earth and the sun changes constantly through the year between 1.47×10^8 km and 1.52×10^8 km as shown in Figure 2.2. This causes the amount of solar radiation or irradiance varies between 1325W/m^2 and 1412W/m^2.The average value is denoted as the solar constant:

Solar constant: E_a = 1367W/m^2

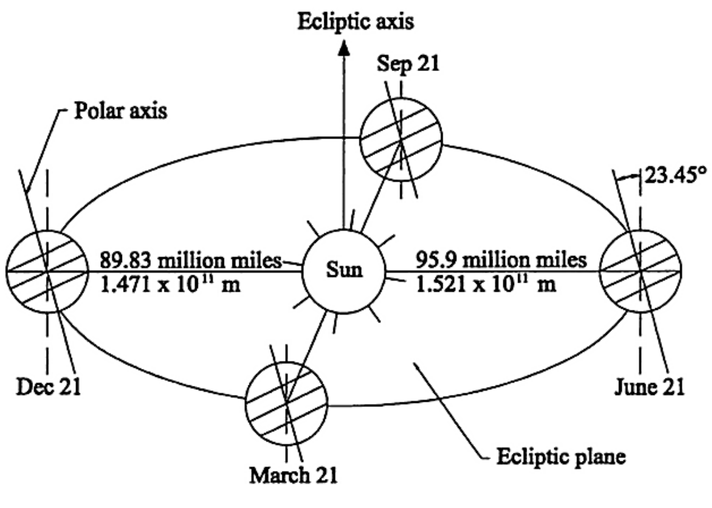

Figure 2.2: Distance of earth from sun

Source: Goswami, Kreith, & Kreider (2000)

Solar radiation or better known as insolation varies according to condition. Although cloud and weather also affect the amount of insolation, however since it is unpredictable and irregular, thus it is difficult to predict the amount of insolation receive accurately. The two major reason of changing in solar radiation which is fixed are the location as the earth rotates on its axis around the earth together with the angle and duration of solar intensity at the given area. One of the ways to determine the amount of solar radiation is by using Lambert's Law, which is the name for an 18th century German scientist, Johann Lambert. Lambert developed a formula where the intensity of irradiance can be calculated using the angle of the sun's zenith angle or the angle of the sun from 90° directly overhead. By using Lambert's law one can calculate the amount of solar radiation based on the latitude. (Petersen, Sack, & Gabler, 2011)

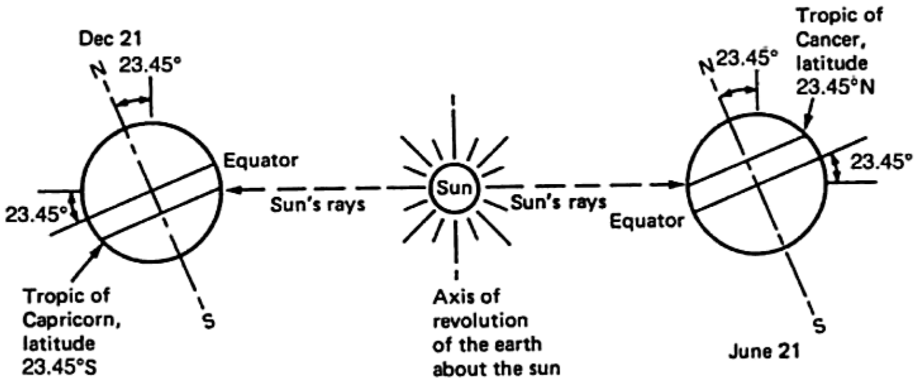

Figure 2.3: The Earth rotates around the sun at axis 23.45°

Source: Goswami, Kreith, & Kreider (2000)

Malaysia is a blessed country for it is placed near the equator. This mean Malaysia is a very suitable place to develop its solar project. There is no changing of season to affect the amount of solar radiation collected. The only thing influences the variation in solar radiation are the cloud and the monsoon. University Malaysia Pahang Pekan Campus is placed at latitude: 3.54° and Longitude: 103.44°. (Zwiefelhofer, 2012)

Tilted angle and the direction where the solar panel is pointing are very important to obtain the most energy from the sun. To optimize the system, solar panel should face true north in the southern hemisphere and true south in the northern hemisphere. The angle between the earth-sun line and the plane through the equator is called solar declination, δ. The solar declination is estimated using Eq. (2.1):

$$\delta=23.45 \sin\left(360\frac{284+n}{365}\right) \tag{2.1}$$

Source: Teliat, Falayi, & Rabiu (2001)

Where

n = the day number during a year with January 1 being n = 1.

n = Leap year/ Non leap year + Day

Table 2.1: number of n for each month

Months	**Non Leap Year**	**Leap Year**	**Date Equal To Monthly Average**
January	0	0	17
February	31	31	16
March	59	60	16
April	90	91	15
May	120	121	15
June	151	152	11
July	181	182	17
August	212	213	16
September	243	244	15
October	273	274	15
November	304	305	14
December	334	335	10

Source: Klein (1977)

Table 2.2 shows the average sunlight hours receive by Malaysia based on month. Each month Malaysia receives different amounts of sunlight hour since it is not on the equator but slightly above it. Based on Malaysian Meteorological Department, Malaysia receives an average of 6 hours of sun per day. Table 2.2 shows the amount of time within a month where one can expect the high amount of solar radiation.

Table 2.2: Average sunlight hours/day in every month

Month	**Average Sunlight Hours/ Day**
January	6.2
February	7.4
March	6.5
April	6.3
May	6.3
June	6.6
July	6.5
August	6.3
September	5.6
October	5.3
November	4.9
December	5.4

2.4 EVACUATED TUBE SOLAR COLLECTOR (ETSC)

ETSC is one of the solar thermal water systems available in the market. It can save money and reduce pollution compared to conventional energy sources. Solar thermal systems are cheap and efficient compared to solar photovoltaic systems, as making sunlight into heat is easier than making sunlight into electricity. Typical new thermal absorption coatings absorb 98 % of solar energy while commercial PV systems do well to change 15 % of incoming solar into electricity. (Wenham, 2006). Even when grid electrical power is available, solar hot water systems can pay for themselves in electrical energy savings. Solar water heating is a way consumer can save money in a "Green" way. (NRCan, 2003)

Evacuated tube collectors (ETC) are the most efficient (conversion efficiency of over 90 %). The collectors are usually made of parallel rows of transparent glass tubes. Each tube contains a glass outer tube and inner glass or metal tube attached to a fin as the absorber. Air is removed, or evacuated, from the space between the two tubes to form a vacuum, which eliminates conductive and convective heat loss.

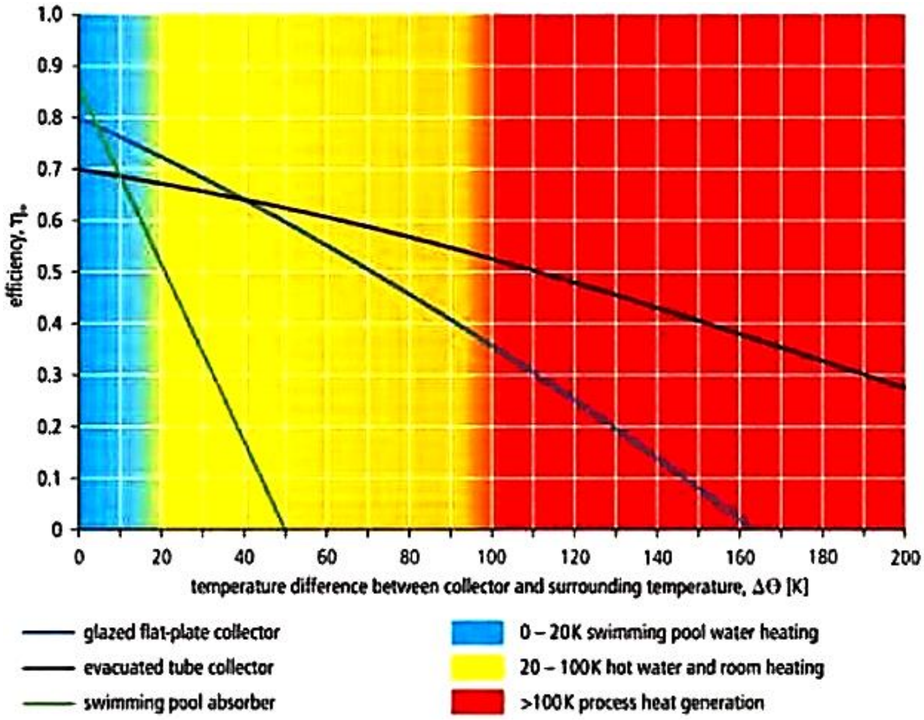

Figure 2.4: Efficiency Characteristic Curves for Different Types of Solar Collector and Their Areas of Application (at irradiation of 1000W/m^{2}K)

Source: Earthscan (2012)

Figure 2.4 shows the amount of efficiency produce by different type of collector. ETSC shows the optimum amount of efficiency graph since the amount of efficiency drop is the smallest. For this project water will be used as the working fluid in the ETSC. Since the efficiency of ETSC is the highest overall between 27°C to 100°C which is for the average Malaysia room temperature and boiling point of water. ESTC is the best solar collector in Malaysia. Since the working fluid used is water, thus it will evaporate at 100°C. A control system will be design and fabricated in this project to ensure that the temperature inside the ETSC never reaches boiling point to protect it from damages.

2.5 PHOTOVOLTAIC

There are three types of solar photovoltaic panel in the market which is monocrystalline, polycrystalline and amorphous thin film. Different types of panel have different type of advantages and disadvantages which is shown in Table 2.3.

Table 2.3: Description, advantages and disadvantages of different type of solar panel

Type	Description	Advantages	Disadvantages
Monocrystalline	▪ Composed of cells cut from a piece of continuous crystal ▪ Black in colour	▪ Longer life span ▪ Performs better than a similarly rated polycrystalline solar panel at lower light and lower temperature conditions. ▪ Space efficient ▪ Efficiency rate around 12 % to 19 %	▪ Slightly more expensive than polycrystalline
Polycrystalline	▪ Blue in colour	▪ Cost less due to simpler making process ▪ Good in hotter weather ▪ Efficiency rate around 13 % to 16 %	▪ Not as efficient due to less pure silicon ▪ Need a larger area to produce same power output as monocrystalline
Thin-Film or Amorphous	▪ Not crystalline silicon	▪ Use least amount of silicon ▪ Can be made flexible and lightweight	▪ Less stable than crystalline, causing degradation over time ▪ Efficiency at 6 % - 9 %

Source: M & Rahman, 2012 and Energy Informative (2013)